DISSECTION AND DISSECTING ANEURYSMS OF THE AORTA: TWENTY-YEAR FOLLOW-UP OF FIVE HUNDRED TWENTY-SEVEN PATIENTS TREATED SURGICALLY

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Dissection and dissecting aneurysms of the aorta: Twenty-year follow-up of five hundred twenty-seven patients treated surgically

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THE DISEASE OF dissection and dissecting aneurysms of the aorta has been known since the sixteenth century when it was described in several publications.[36, 37, 41] In his classical treatise on aneurysms, Scarpa[37] referred to Fernelius[15] as the first, in 1542, to propose that an aneurysm may be caused by pathologic distension of all the coats of an artery. In 1628, Sennertus[38] described aortic dissection but made no distinction between the process and aneurysmal formation. In 1769, Morgagni[29] recorded a clear description of the anatomic and pathologic changes in dissecting aneurysms. A more detailed and accurate description of the disease was presented by Maunoir[26] in 1802. The term "dissecting aneurysm" was first designated by Laennec,[24] in 1826, as "anévrisme disséquant." During the remainder of the nineteenth century, a number of investigators reported observations on the pathology, histoanatomy, and pathogenesis, further clarifying the nature of the disease.† Despite these observations there remained some confusion and uncertainties about the pathogenesis of the disease. Much of this was resolved in 1934 by Shennan[41] in his classical treatise on the subject and his extensive investigations resulting in the conclusion that the most significant underlying cause of dissection was medial degeneration.

The gravity of the disease with its rapidly fatal course has long been recognized. This was first indicated by Shennan,[41] who found in his analysis of a collected series that death occurred within 24 hours in 58% and within 1 week in 26%. Since then, a number of published reports on the natural course of the disease have shown that more than half the patients die within a few weeks after the initial dissection and about 90% within a few months, with only a few patients surviving 1 year.* In a more recent report, Anagnostopoulos and associates[1] found in an analysis of a collected series of 963 patients from six reported series that death occurred within 1 week in 70% and within 3 months in 90%.

Gurin and associates[17] first attempted to use surgical treatment for this disease in 1935 in a patient with right iliac occlusion produced by the dissection. Although they successfully restored circulation to the limb by creating a reentry passage at the site of the obstruction, the patient died of renal failure. In 1948, Paullin and James[33] reported a second attempt, which consisted in trying to strengthen the wall by cellophane wrapping, but this proved unsatisfactory. In 1953, Johns[22] reported an unusual case in which a ruptured dissecting abdominal aneurysm was repaired by suture, but the patient died of renal failure. Two years later, Shaw[39] reported a case of acute arterial insufficiency of the leg which was relieved by a procedure somewhat similar to that used by Gurin and associates, but the patient also died of renal failure.

Our surgical experience with this disease began in 1954, with a 58-year-old white man with a dissecting aneurysm of the descending thoracic aorta.[9] The dissecting aneurysm was excised above its origin. The false lumen in the distal end of the aorta was obliterated by reapproximation of the dissected layer with interrupted

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†See references 18, 20, 34, 35, 40, 43.

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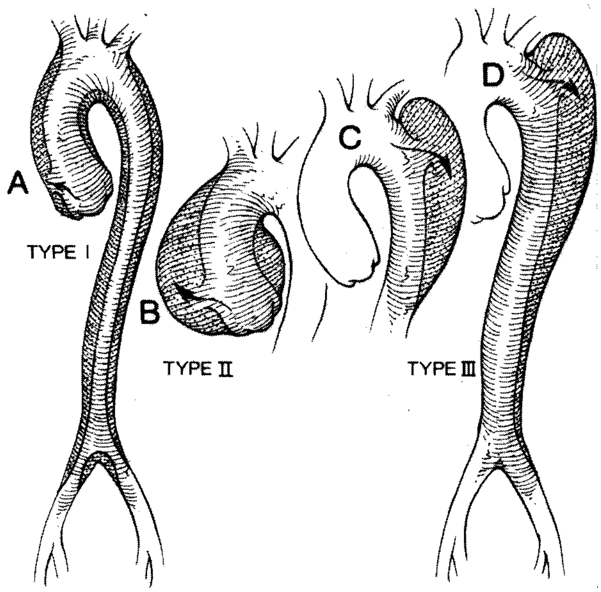

Fig. 1. Drawing illustrating classification of dissection and dissecting aneurysms of the aorta into three types depending on site and extent of dissecting process. Arrows indicate the most common sites of the initial intimal tear in each type, but in some cases this may occur at other sites and because of retrograde and distal dissection and the occurrence of more than one tear, it is not always possible to determine the original site of dissection.

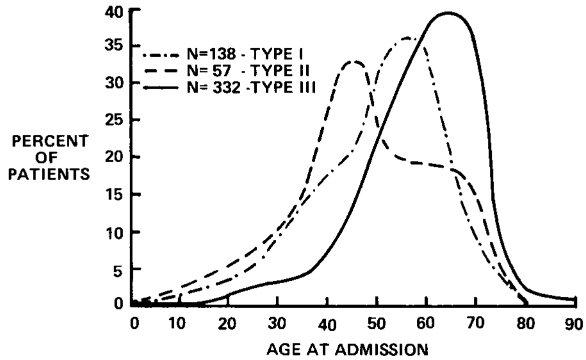

Fig. 2. Age distribution of 527 patients with dissecting aneurysms of the aorta according to type.

sutures and restoration of aortic continuity by end-to-end anastomosis. The patient had an uneventful recovery.

After this first successful repair of a dissecting aneurysm of the aorta, additional experience led to a better understanding of the anatomic and pathologic patterns of the disease, resulting in certain conceptual changes that provided more effective methods of surgical treatment for the various forms of the disease. Accordingly, a classification of these different forms of the disease was devised along with appropriate surgical treatment for each type[8, 9, 11-14] (Fig. 1). This presentation is concerned with an analysis of our experience with 527 patients treated surgically during a period of 28 years.

CLASSIFICATION

As indicated in previous publications, accumulated surgical experience with dissecting aneurysms of the aorta, along with anatomic, pathologic, and aortographic studies, provided the basis for our classification into three groups (Fig. 1). The essential criteria of this classification are the extent of the dissecting process and its anatomic location. Misinterpretations of this classification with emphasis based solely on the site of intimal tears have led to some confusion and even proposals of other methods of classification.* Although the initial intimal tear occurs more commonly in the ascending aorta and the proximal descending thoracic aorta, it may also occur in the aortic arch and other sites of the aorta. Since both retrograde and distal dissection may take place after the initial intimal tear, it may not be possible by clinical and aortographic studies to determine the original site of the dissection. Moreover, the fact that more than one intimal tear or opening between the true and false lumen may occur makes it difficult to establish the original site. As will be shown, the results of our accumulated experience have confirmed the validity of our classification and its usefulness in proper treatment.

Type I. The essential characteristic feature of type I is that the ascending aorta, as well as the remaining distal portions of the aorta, is involved in the dissecting process (Fig. 1). Although in most patients the intimal tear arises as a transverse opening in the anterior wall of the proximal portion of the ascending aorta, it may also begin in the aortic arch or even in the descending thoracic aorta, with retrograde dissection to the aortic root and distal dissection throughout the remainder of the aorta. Aortic valvular incompetence is sometimes present and is usually produced by dilatation of the annulus or lack of support or fixation of the intimal attachment of the valves resulting from proximal extension of the dissecting process and thus causing failure of the valves to meet properly in the closed position. The most common and often fatal complications of this type of dissection include rupture of the

*See references 5, 6, 28, 32, 42, 46.

Table I. Age data according to type of dissecting aortic aneurysm

	Type I	*Type II*	*Type III*
Age (years)			
Mean	50.2	47.3	57.9
Median	53.0	48.0	60.0
Youngest	9.0	16.0	14.0
Oldest	72.0	75.0	89.0

Table II. Sex distribution according to type of dissecting aortic aneurysm

		Males		*Females*	
Type	*Total*	*n*	*%*	*n*	*%*
I	138	111	80.4	27	19.6
II	57	47	82.5	10	17.5
III	332	278	83.7	54	16.3
Total	527	436		91	

wall of the false lumen with fatal hemorrhage into the mediastinum, pericardial effusion and hemorrhage with progressive cardiac tamponade, obstruction of vital branches of the aortic arch with resultant cerebral ischemic or coronary insufficiency, and severe aortic valvular incompetence with acute heart failure. This type occurred in 26.2% of the patients in our series.

Type II. In type II, the dissecting process is limited to the ascending aorta and is usually characterized by a transverse tear in the intima anteriorly just above the aortic valves with separation of the intramural layers that terminates usually just proximal to the origin of the innominate artery (Fig. 1). This type is often associated with aortic valvular incompetence and sometimes with Marfan's syndrome. Circumferentially the posterior wall of the aorta may remain intact. This type occurred in 10.8% of the patients in our series.

Type III. In most patients with type III, the dissecting process arises just distal to the origin of the left subclavian artery and extends distally for a varying distance. In some patients, the dissecting process is limited to the descending thoracic aorta, which we have termed type III a (Fig. 1). More often, however, it extends below the diaphragm to involve the abdominal aorta and occasionally the iliac arteries, which we have termed type III b. This type occurred in 63% of the patients in our series.

In this analysis of our cases the patients with each type have been classified according to onset of the disease into acute (less than 2 weeks), subacute (2 weeks to 2 months), and chronic (more than 2 months). The respective incidences of this classification were 27.1%, 15.7%, and 57.1%.

Table III. Incidence of hypertension according to type of dissecting aortic aneurysm

		Hypertensive patients	
Type	*Total patients*	*n*	*%*
I	138	119	86.2
II	57	39	68.4
III	332	300	90.4
Total	527	458	86.9

CLINICAL FEATURES

The ages of the patients ranged from 9 to 89 years; almost four-fifths were in the fifth to seventh decades of life. The median for the ages appeared to be highest in type III and lowest in type II (Table I, Fig. 2). The characteristic predominance of male over female patients in each type is shown in Table II. Table III shows the typically high incidence of hypertension in all three types, ranging from 68% in type II to 93% in type III.

Symptoms on admission are listed in Table IV according to type of aneurysm, and the preoperative findings and medication on admission are given in Tables V and VI. The significance of the differences among the preoperative variables and the type of dissection, evaluated by an χ^2 contingency table analysis for each cross-tabulation, is also shown in Tables IV to VI. The variables which are significantly differently distributed among the types of aneurysm were: pain (highest frequency in types I, III a, and III b), symptoms of congestive heart failure (types I and II), rupture (types I and III b), history of syncope/stroke (type I), Marfan's syndrome (types I and II), signs of congestive heart failure (types I and II), digitalis usage (types I and II), and Inderal usage (types I and III b).

The relation between the age of the dissection (acute, subacute, or chronic) and the preoperative variables listed in Tables IV to VI was similarly analyzed; the results are shown in Table VII. The variables listed varied significantly in prevalence according to the age of the dissection. Also shown are the subgroups according to age of dissection in which the prevalence of the variable was highest. As would be expected, pain, syncope, peripheral ischemia, rupture, and renal failure were most significantly associated with acute stages of the disease.

Table IV. Clinical manifestations on admission by type of dissecting aortic aneurysm

	Type I		*Type II*		*Type III a*		*Type III b*		
Clinical manifestation	%	*n*	%	*n*	%	*n*	%	*n*	*P**
Pain	71	98	46	26	80	66	76	188	< 0.01
Angina	17	24	21	12	16	13	22	55	NS
Congestive heart failure	45	62	61	35	2	2	2	5	< 0.01
Rupture	14	19	4	2	12	10	7	17	< 0.01
Syncope/stroke	14	19	2	1	5	4	3	7	< 0.01
Paraparesis	3	4	0	0	1.2	1	2	5	NS
History of renal failure	4	5	0	0	4	3	5	13	NS
Cough	5	7	0	0	2	2	4	11	NS
Claudication	3	4	0	0	2	2	4	11	NS
Peripheral ischemia	13	18	0	0	4	3	6	15	NS
Visceral ischemia	1.4	2	0	0	1.2	1	0.8	2	NS
Hoarseness	1.4	2	4	2	6	5	4	9	NS
Dysphagia	0.7	1	0	0	1.2	1	0.8	2	NS
Hemoptysis	1.4	2	0	0	1.2	1	2	6	NS
Symptom free	10	8	14	8	14	12	15	37	NS
History of trauma	1.5	2	5	3	2	2	3	8	NS

*For significance of differences between groups derived from cross-tabulations of presence or absence of variable versus the types of aneurysms.

Table V. Preoperative findings by type of dissecting aortic aneurysm

	Type I		*Type II*		*Type III a*		*Type III b*		
Preoperative findings	%	*n*	%	*n*	%	*n*	%	*n*	*P**
Marfan's syndrome	22	30	30	17	4	3	6	15	<0.01
Congestive heart failure (signs)	30	41	39	22	4	3	5	12	<0.01
Myocardial infarction—electrocardiography	11	15	7	4	10	8	14	34	NS
Coronary disease on catheterization	5	7	16	9	5	4	7	17	NS
Renal failure	2	3	4	2	6	5	8	20	NS
Stroke	6	8	0	0	7	6	3	7	NS
Coarctation of aorta	1.5	2	1.8	1	1.2	1	1	2	NS
Diabetes	1.5	2	0	0	4	3	4	9	NS
Hyperlipidemia	0.7	1	5	3	1	1	2	4	NS
Hypertension	87	120	68	39	89	74	93	232	NS
Other	4	6	1.8	1	1.2	1	1	3	NS

*For significance of differences between groups derived from cross-tabulations of presence or absence of variable versus the types of aneurysms.

SURGICAL TREATMENT

Experience has shown that it is extremely important to make a precise diagnosis of the type of dissection as soon as possible after onset of the disease because fatal complications develop rapidly in this early period. Moreover, the method of surgical treatment depends on the type of dissection. Although noninvasive diagnostic methods are useful, aortography has proved to be the best procedure for precisely establishing the type of dissection.

The initial treatment of the patient, particularly in the acute stage of the disease, is directed toward stabilization of the cardiovascular system and requires careful and continuous monitoring of the patient's condition in the intensive care unit.[14] Special emphasis is placed on maintaining blood pressure as low as is consistent with adequate cerebral, cardiac, and renal functions. This period of stabilization for several days or longer is desirable for several reasons. For one thing, it enables the surgeon to decide on the best time for an

Table VI. Medication on admission by type of dissecting aortic aneurysm

	Type I		*Type II*		*Type III a*		*Type III b*		
Medication	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*P**
Digitalis	46	63	53	30	17	14	18	46	<0.01
Diuretics	36	49	37	21	33	27	44	110	NS
Inderal	22	31	12	7	7	6	25	50	<0.02
Reserpine	5	7	4	2	1	1	7	17	NS
Other antihypertensive agents	33	46	23	13	34	28	44	109	NS
Other	0.7	1	0	0	0	0	1	2	NS

*For significance of differences between groups derived from cross-tabulations of presence or absence of variable versus the types of aneurysms.

Table VII. Significant association of age of dissection with preoperative variables

Variable	*Subgroups with highest prevalence of variable*	χ^2	*df*	*P**
Pain	Acute, subacute	58.172	2	0.0001
Syncope	Acute	23.137	2	0.0001
Peripheral ischemia	Acute	45.190	2	0.0001
Rupture	Acute	30.034	2	0.0001
Symptoms of renal failure	Acute	45.137	2	0.0001
Angina	Acute, chronic	6.183	2	0.045
Coronary artery disease (by catheterization)	Acute, chronic	9.000	2	0.011
Marfan's syndrome	Chronic	11.498	2	0.003
Diuretic usage	Chronic	11.406	2	0.003
Congestive heart failure	Chronic	16.43	2	0.0003

Legend: df, Degrees of freedom.
*For significance of differences between groups derived from cross-tabulations of presence or absence of variable versus age of the dissection.

elective operation based on certain indications, and thus to reduce the risk of operation. For another, the aortic tissues during the early stages of dissection are extremely friable and do not hold sutures well. Accordingly, postponing the operation permits the tissues to become less friable and to hold sutures better, and thus reduce the surgical risk. Under certain conditions, however, emergency surgical treatment is indicated: evidence of imminent rupture, severe aortic valvular insufficiency with acute heart failure, cerebral ischemia with innominate or carotid arterial obstruction, progressive pericardial effusion, and occlusion of the coronary arteries and other vital aortic branches.[7, 30, 31]

Type I. The operation for type I is performed with use of cardiopulmonary bypass. In most patients with this type, the ascending aorta is resected, the dissected wall is reapproximated distally, and the resected segment is replaced with a woven Dacron graft[2, 12] (Fig. 3). In the occasional patient who has minimal anatomic disruption and distortion of the aorta at the site of intimal laceration, it may be possible to approximate the inner and outer layers of the dissecting process proximally and distally by suture with the use of Dacron felt baffle and then anastomose these sutured edges of the transected aorta end-to-end[12, 30, 31] (Fig. 4). In still other cases, after removal of the anterior dissected portion of the ascending aorta and reapproximation of the dissected wall, it may be possible to repair the defect by patch-graft angioplasty. Associated aortic valvular incompetence is usually produced by dilatation of the annulus or lack of support or fixation of the intimal attachment of the valves, due to proximal extension of the dissecting process, which causes failure of the valves to meet properly in the closed position. Although valvular resuspension has proved satisfactory in some cases, we prefer aortic valvular replacement.[12] If the dissecting process involves the origin of the coronary arteries, aortocoronary bypass may be performed, or a button of the aortic wall around the coronary orifice may be sutured to an opening in the aortic graft (Fig. 5).

Type II. Since the dissecting process in type II is limited to the ascending aorta, the operative procedure consists in resection of the ascending aorta and dissec-

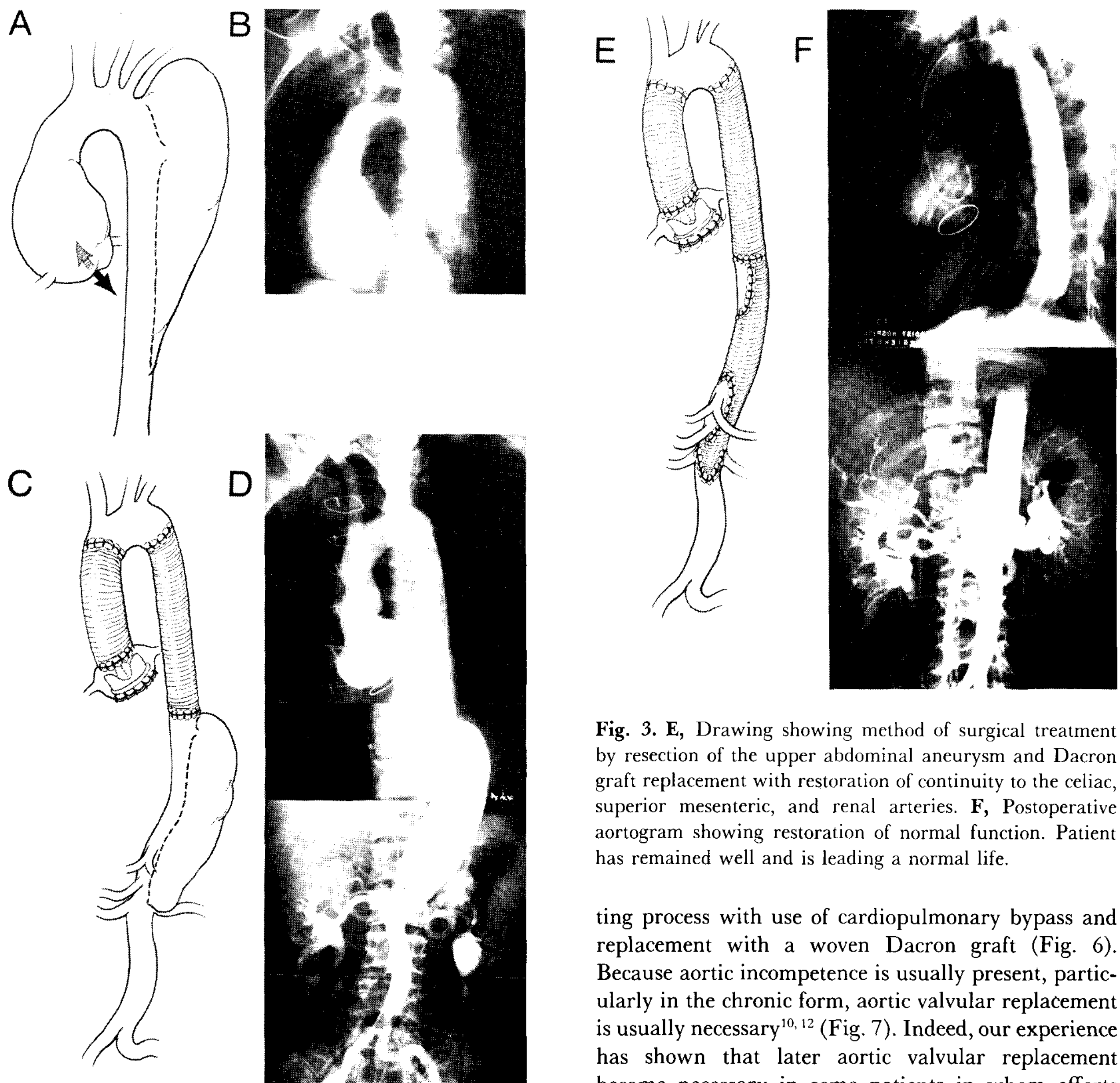

Fig. 3. A, Drawing and **B,** aortogram in a 26-year-old white man with some stigmata of Marfan's syndrome showing type I dissecting aneurysm involving ascending and descending thoracic aorta with aortic insufficiency. Resection of the ascending aorta with Dacron graft replacement and aortic valvular replacement was performed. Two weeks later he had resection of the dissecting aneurysm of the descending thoracic aorta with Dacron graft replacement after the outer and inner layers of the false lumen were approximated with attachment of the graft distally to the normal lumen. **C,** Drawing and **D,** aortogram made 8 months later showing satisfactory graft replacement of ascending and descending thoracic aorta but development of an extensive aneurysm of the upper abdominal aorta.

Fig. 3. E, Drawing showing method of surgical treatment by resection of the upper abdominal aneurysm and Dacron graft replacement with restoration of continuity to the celiac, superior mesenteric, and renal arteries. **F,** Postoperative aortogram showing restoration of normal function. Patient has remained well and is leading a normal life.

ting process with use of cardiopulmonary bypass and replacement with a woven Dacron graft (Fig. 6). Because aortic incompetence is usually present, particularly in the chronic form, aortic valvular replacement is usually necessary[10, 12] (Fig. 7). Indeed, our experience has shown that later aortic valvular replacement became necessary in some patients in whom efforts were made to avoid the procedure during the original operation (Fig. 8). In the acute form, it may be possible to avoid this procedure by resuspension of the valves.[12, 44] Involvement of the coronary artery may be treated as described earlier.

Type III. The treatment for type III consists essentially in resection of the diseased segment and replacement with a woven Dacron graft through left lateral thoracotomy.[8, 11-13] Since the dissecting process rarely extends proximally beyond the origin of the left subclavian artery, the graft can usually be anastomosed proximally to the normal lumen. In type III a, in which the dissecting process is limited to the descending

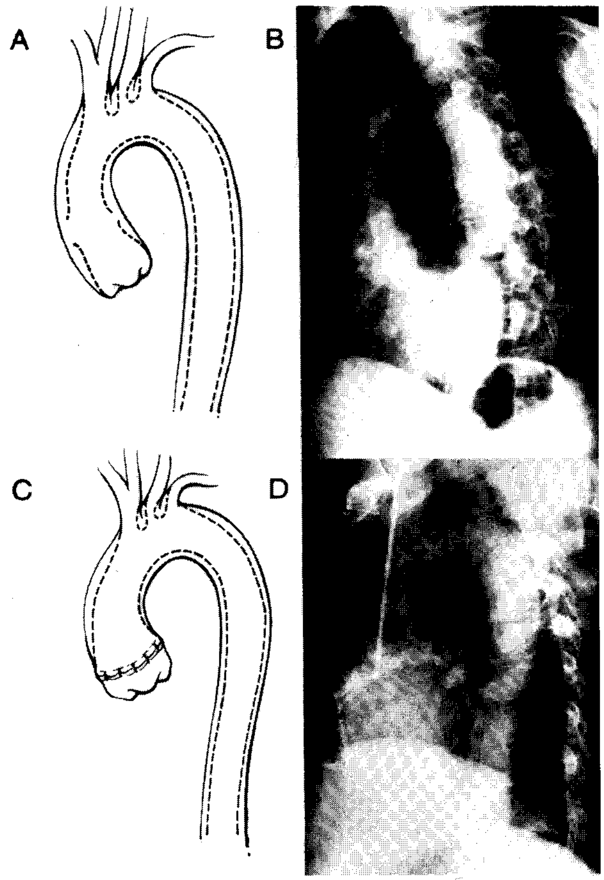

Fig. 4. A, Drawing and **B,** preoperative aortogram in a 37-year-old white man showing type I dissecting aneurysm of the aorta. **C,** Drawing showing method of surgical treatment and **D,** aortogram made 18 years after operation.

thoracic aorta, the distal end of the graft can also be attached to the normal aortic wall after removal of the entire dissecting process (Fig. 9). In most patients with type III b, in which the dissecting process extends below the diaphragm, there is a tendency for the false lumen to be smaller near the diaphragmatic hiatus. In such cases, the inner and outer walls of the dissection are first approximated by suture with use of a Dacron velour patch baffle, and the distal end of the graft is anastomosed to the normal lumen (Fig. 10). In occasional cases the procedure may be modified if the dissecting process does not involve the celiac and superior mesenteric arteries by extending the operation as a thoracoabdominal approach with removal of all the dissecting process (Fig. 11). In light of certain observations derived from the present study, consideration is being given to modifying this procedure as discussed later in this report.

In all three types, resection with graft replacement was the most common procedure, being performed on 94% of the patients. Patch-graft angioplasty was used in only 3.4% of the patients in the series, and intimal reattachment is slightly more than 2%, primarily in the early years. Among the associated surgical procedures, aortic valvular replacement was performed in slightly less than half the patients and annuloplasty in about 15%, all with types I and II. Coronary reimplantation of coronary artery bypass was done in about 12% of patients, also all with types I and II.

RESULTS

Analysis of the series under discussion disclosed a number of significant observations. As a consequence of refinements in both preoperative preparation and surgical technique, the operative mortality rate has progressively decreased. Accordingly, since 1970 the operative mortality rates have been reduced from 27% in type I, 15% in type II, and 19% in type III to 20%, 8%, and 16%, respectively. As expected, the operative mortality rate was highest in the acute stage of the disease, being almost twice that in the subacute and chronic stages in all three types. The most common cause of operative deaths was rupture of the aneurysm (26%); this incidence emphasizes the unpredictable and often potentially fatal nature of this disease. Myocardial infarction accounted for 25% of the deaths, followed by congestive heart failure (24%) and respiratory failure (10%).

The postoperative complications are listed in Table VIII; again the significance of differences in prevalences among the types of dissections was analyzed by the χ^2 contingency table technique. Paraplegia was most prevalent in type III b, as was the combined prevalence of paraplegia, paraparesis, and neurogenic bladder (combined spinal and neurologic). Postoperative stroke was more prevalent in types I and III a. The incidence of the other complications did not differ significantly in the different types of aneurysm.

We have observed little or no change in the incidence of spinal cord ischemia as a complication in type III since 1970 when we abandoned various procedures that we had tried in an effort to prevent this complication, including hypothermia, shunts, left atrial femoral bypass, and femorofemoral bypass. Since 1970 we have concentrated on simplifying and expediting the surgical procedure and have observed a reduction in mortality rate and other complications.

Our long-term follow-up results (93% complete) have provided gratifying evidence that surgical treatment has significantly altered the highly fatal natural

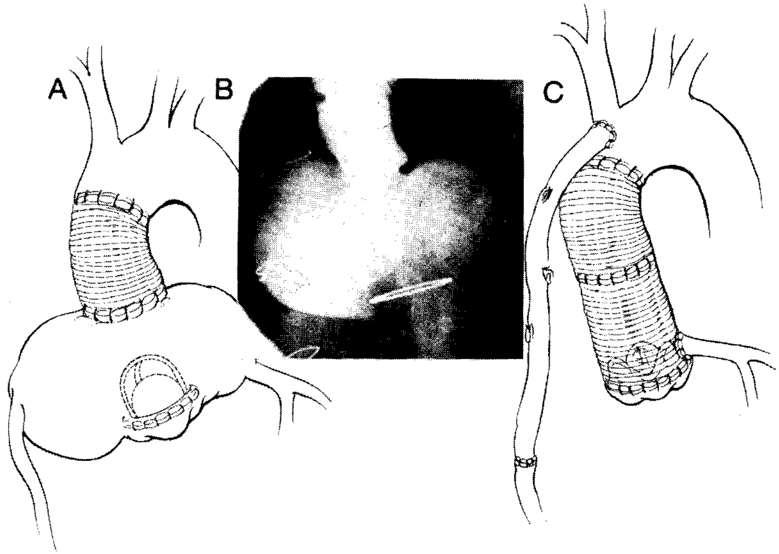

Fig. 5. A, Drawing and **B,** aortogram in a 31-year-old white man with type I dissecting aneurysm of the ascending aorta associated with aortic insufficiency treated elsewhere in 1972 by resection and Dacron graft replacement and in 1978 by aortic valvular replacement now showing extensive aneurysm of sinus of Valsalva involving origin of both coronary arteries resulting from inadequate resection of aneurysmal process at original operation. **C,** Drawing showing method of surgical treatment consisting in resection of remaining aneurysm and replacement with Dacron graft and bypass autogenous vein graft from distal ascending aorta to right coronary artery and attachment of left coronary ostia to Dacron graft. Patient has remained well for the past 4 years.

Table VIII. Postoperative complications according to type of dissecting aortic aneurysm

	Type I		*Type II*		*Type III a*		*Type III b*		
Complication	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*P**
Proximal progression of dissection	3	4	0	0	5	4	8	11	NS
Distal progression of dissection	2	3	1.7	1	1.2	1	2	5	NS
Paraplegia	2	3	0	0	0	0	7	17	<0.01
Paraparesis	2	3	0	0	6	5	4	10	NS
Neurogenic bladder	0.7	1	0	0	2	2	5	12	NS
Combined spinal neurologic	4	6	0	0	8	7	12	29	<0.01
Myocardial infarction	4	6	5	3	8	7	5	12	NS
Postoperative stroke	7	9	0	0	7	6	2	6	<0.05
Renal failure	7	9	4	2	2	2	5	13	NS
Reoperation	1.4	2	0	0	0	0	1.6	4	NS
Hemothorax	7	9	4	2	2	2	10	25	NS
Respiratory insufficiency	7	10	0	0	8	7	9	23	NS
Pulmonary embolism	0	0	0	0	1.2	1	1.2	3	NS
Rupture	7	9	0	0	4	3	8	21	NS
Graft infection	7	1	1.7	1	0	0	0.4	1	NS
Atrial fibrillation	4	6	0	0	5	4	3	7	NS
Gastrointestinal bleeding	1.4	2	1.7	1	2	2	3	7	NS
Other	9	12	7	4	0	0	4	10	NS

*For significance of differences between groups derived from cross-tabulations of presence or absence of variable versus the types of aneurysm.

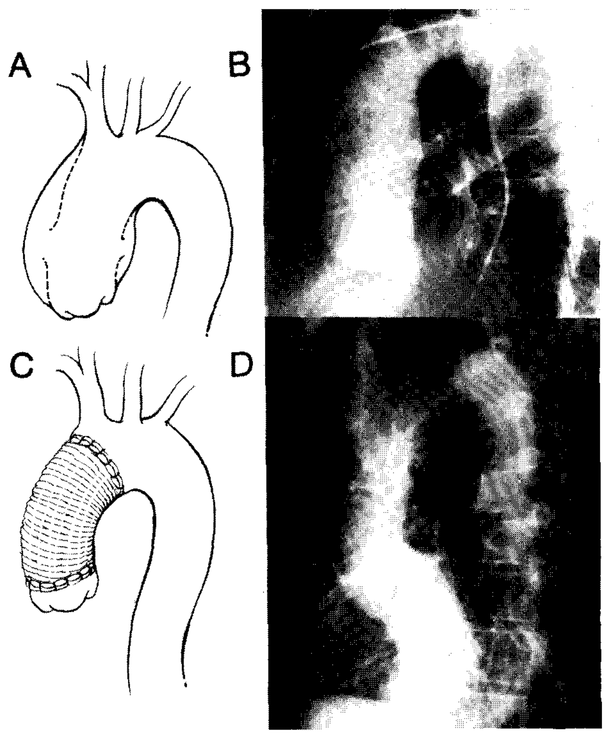

Fig. 6. A, Drawing and **B,** preoperative aortogram in a 53-year-old white man showing type II dissecting aneurysm of ascending aorta. **C,** Drawing showing method of surgical treatment consisting in resection and Dacron graft replacement along with annuloplasty to correct aortic insufficiency and **D,** postoperative aortogram showing restoration of normal function. Patient has remained well almost 20 years after operation.

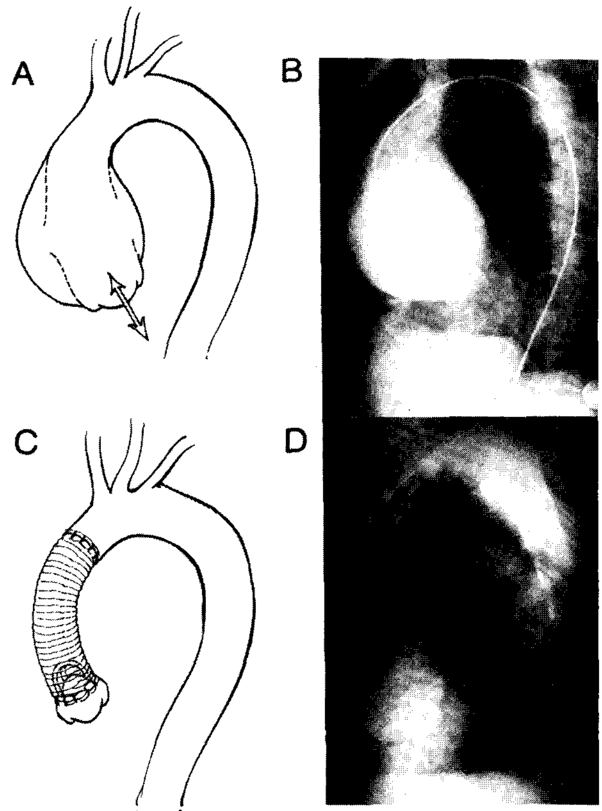

Fig. 7. A, Drawing and **B,** preoperative aortogram in a 42-year-old white man showing type II dissecting aneurysm of ascending aorta associated with aortic insufficiency. **C,** Drawing showing method of surgical treatment consisting in resection, Dacron graft replacement, and aortic valvular replacement. **D,** Aortogram made 18 years after operation showing normal function.

course of the disease. This is evident from comparison of the survival rates of nonsurgically treated patients with our results extending for more than 20 years after operation. In a collected series of nonsurgically treated patients,[1] for example, only 10% survived 3 months and none longer than 3 years, whereas in our series the overall 5-year survival rate was 57%; the 10-year survival rate, 32%; and the 20-year survival rate, about 5% (Fig. 12). The survival rate was somewhat higher in types I and II than in type III (Fig. 13).

One of the most significant observations derived from this analysis is the subsequent formation of an aneurysm and its effect upon survival. Indeed, the development and rupture of such aneurysms were the most common cause of late deaths, accounting for 29.3% of all late deaths (Table IX). Particularly noteworthy is the significant difference in the incidence of subsequent aneurysmal formation in the different types of dissection. Thus in types I and III b, the incidences were 30% and 38%, respectively, whereas in type II it was 14% and in type III a, 16% (Table X). In this connection, the importance of control of hypertension is shown by the fact that subsequent aneurysms developed in 45.5% of patients with uncontrolled hypertension and in only 17.4% of those with controlled hypertension.

These observations on the high incidence of subsequent aneurysmal formation and its cause of late deaths suggest certain important considerations in the treatment of these patients. For one thing, they emphasize the need for careful follow-up studies, particularly in patients with type I or III b, in order to detect subsequent aneurysmal formation, which may require surgical correction (Fig. 3). For another, they suggest the desirability of modifying the surgical procedure that we originally described for type III b by extending

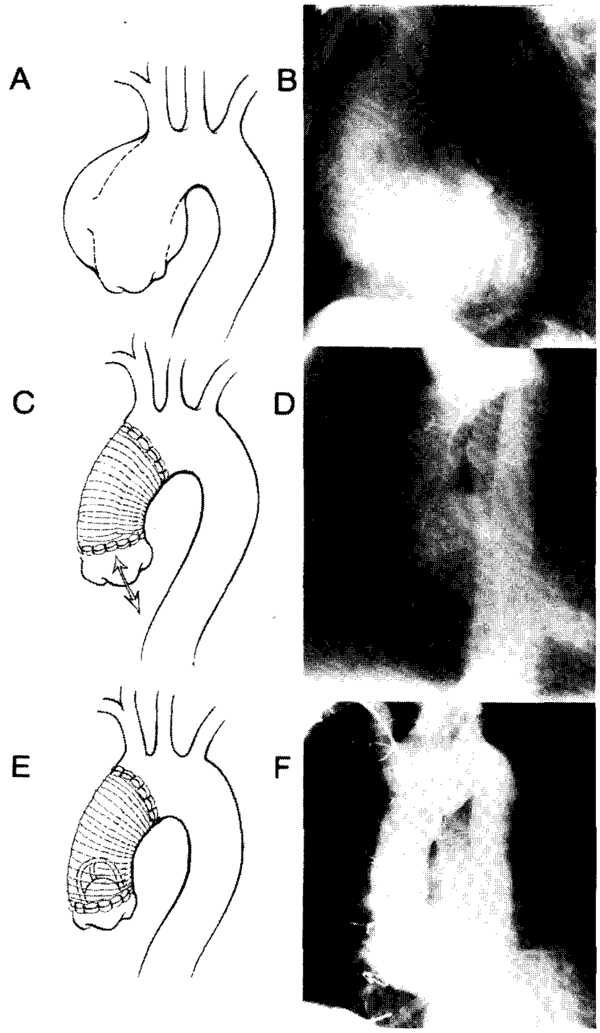

Fig. 8. **A,** Drawing and **B,** preoperative aortogram in a 38-year-old white man showing type II dissecting aneurysm of ascending aorta treated by resection and Dacron graft replacement. **C,** Drawing and **D,** aortogram made 6 years after operation showing severe aortic insufficiency. **E,** Drawing showing aortic valvular replacement. **F,** Aortogram made 12 years after valvular replacement and 18 years after first operation showing normal function.

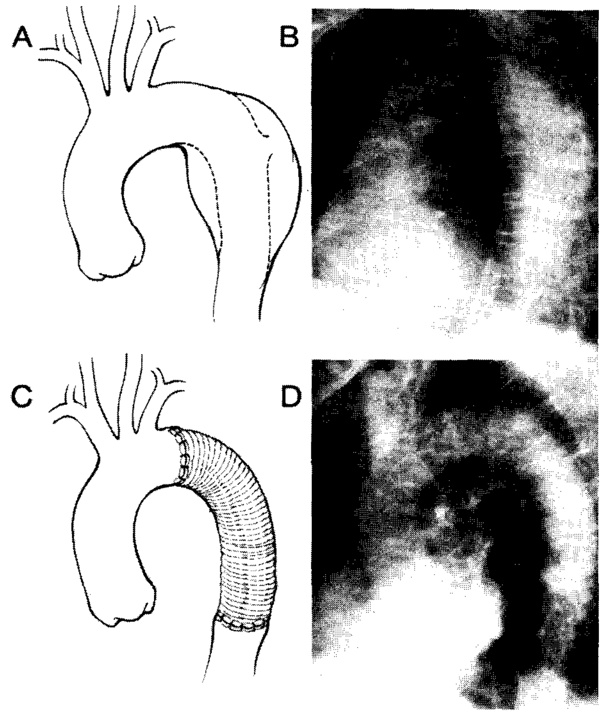

Fig. 9. **A,** Drawing and **B,** preoperative aortogram in a 61-year-old white man with type III a dissecting aneurysm of the descending thoracic aorta. **C,** Drawing showing method of surgical treatment consisting in resection and Dacron graft replacement. **D,** Postoperative aortogram showing restoration of normal function 18 years after operation.

the operation into the abdomen to remove the entire dissecting process and accomplishing the repair in much the same way as that described for a thoracoabdominal aneurysm.[4]

Another important consideration that emerged from these observations is the identification of certain preoperative clinical factors that significantly influence perioperative and overall survival rates. A number of preoperative factors were analyzed by the Cox multivariate statistical techniques for their effect on survival[3] (Tables XI to XIV). The final results of the multivariate analyses (Tables XIII and XIV) indicated that the risk of perioperative death was higher in the elderly and patients with preoperative angina, congestive heart failure, and acute dissection. The overall mortality rate also was higher in such patients, and preoperative stroke also increased the risk of overall mortality. To assess the magnitude of the effect of these preoperative variables, we used the factors shown to be predictive of perioperative death in Table XIII to classify the patients into groups of high, medium, and low risk of perioperative death for each type of aneurysm. The patients were divided into quartiles according to risk with the medium-risk group containing the two middle quartiles. The results of this analysis (Table XV) indicate that the presence or absence of the preoperative variables listed in Table XIII greatly influenced the incidence of perioperative deaths. These results again showed the importance of recognition and careful treatment of coexistent cardiac disease during the perioperative period. To examine the effect of the preoperative clinical variables on overall survival, we obtained 5-year survival curves using the Kaplan-

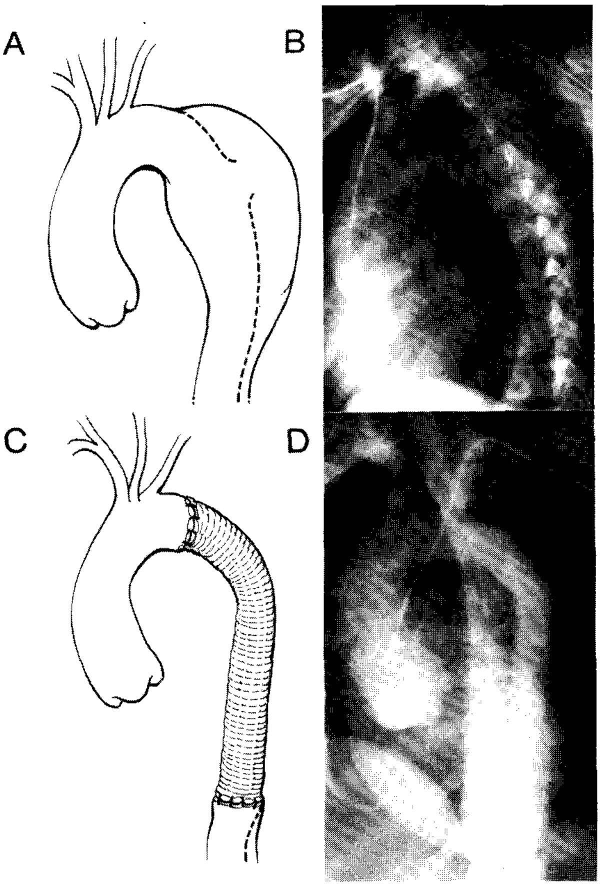

Fig. 10. A, Drawing and **B,** aortogram in a 49-year-old white woman with type III b dissecting aneurysm. **C,** Drawing showing surgical procedure consisting in resection of dissecting aneurysm and replacement with Dacron graft. The outer and inner layers of the dissecting process were reapproximated distally by suture, and the distal end of the graft was anastomosed to the normal lumen. **D,** Aortogram 18 years after operation showing normal function. Patient remains well.

Table IX. Causes of late deaths in 527 patients with dissecting aortic aneurysms treated surgically

	Patients	
Cause	*n*	*%*
Rupture of aneurysm	60	29.3
Myocardial infarction	23	11.2
Stroke	22	10.7
Miscellaneous	22	10.7
Sudden, unknown	14	6.8
Cancer	13	6.3
Congestive heart failure	10	4.9
Pneumonia	7	3.4
Renal failure	4	1.9
Respiratory insufficiency	2	0.9
Pulmonary embolism	1	0.5
Unknown	27	13.2
Total	205	

Table X. Incidence of subsequent aneurysms according to type of dissecting aortic aneurysms

Type	*Operative survivors*	*Patients with subsequent aneurysm or dissection*	*%*
I	104/138	31/104	29.8
II	50/57	7/50	14.0
III a	68/83	11/68	16.2
III b	194/249	73/194	37.6
Total	416/527	122/416	29.0

Meier method.[23] High-, medium-, and low-risk subgroups were defined by quartiles of risk as before except that the variables predictive of overall survival given in Table XIV were used. The survival curves are shown in Figs. 14 to 18. It is apparent that preoperative factors (Table XIV) continue to exert an unfavorable influence on survival even in the late postoperative period and that efforts to identify and treat the patient for these conditions should continue in the late postoperative period.

SUMMARY

A series of 527 patients treated surgically for dissection and dissecting aneurysms of the aorta during a period of 28 years was analyzed. The disease is classified into three major types depending on the location and extent of the dissecting process: type I, in which the dissecting process involves the ascending aorta as well as the remaining portion of the aorta; type II, in which the dissecting process is limited to the ascending aorta; type III a, in which the dissecting process is limited to the descending thoracic aorta; and type III b, in which the dissecting process involves the descending thoracic aorta but extends distally into the abdominal aorta. Evidence is presented to confirm the validity of this classification with regard to both application of appropriate surgical treatment and long-term prognosis.

The ages of the patients ranged from 9 to 89 years, with the majority of patients in the fifth to seventh decades of life. The median for the ages appeared highest in type III and lowest in type II. Male patients were predominant over female patients in a ratio of 5 to 1. Hypertension was a predominant associated factor, being present in 90% in type III, 86% in type I, and 68% in type II.

Certain clinical manifestations on admission were

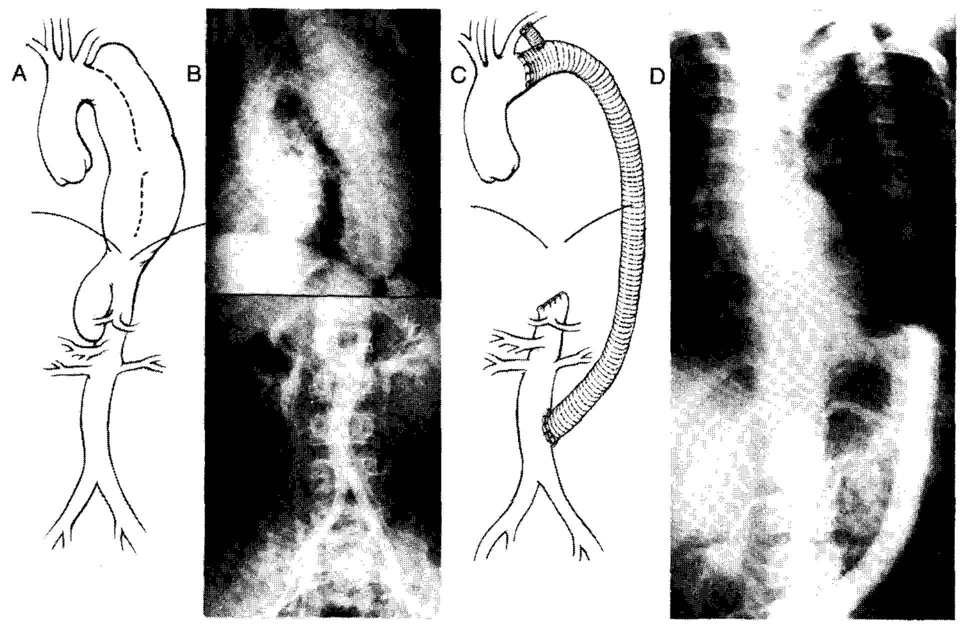

Fig. 11. A, Drawing and **B,** preoperative aortogram in a 14-year-old black boy showing extensive type III b dissecting aneurysm of descending thoracic aorta. **C,** Drawing showing method of surgical treatment consisting in excision of entire dissecting aneurysm through a thoracoabdominal approach and replacement with Dacron graft. **D,** Postoperative aortogram showing restoration of normal function. Patient remains well 22 years after operation.

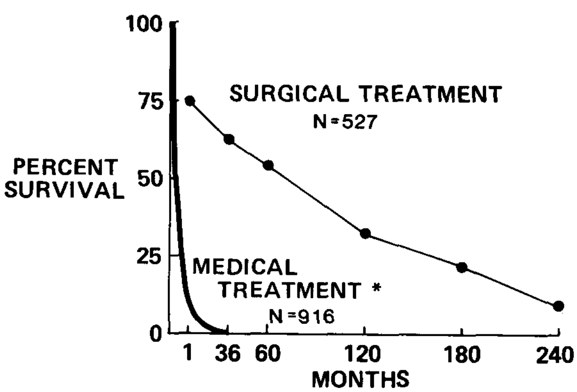

Fig. 12. Survival curves comparing medical and surgical treatment during a period of 20 years in 527 patients with dissecting aneurysms of the aorta. *Data from Anagnostopoulos et al.[1]

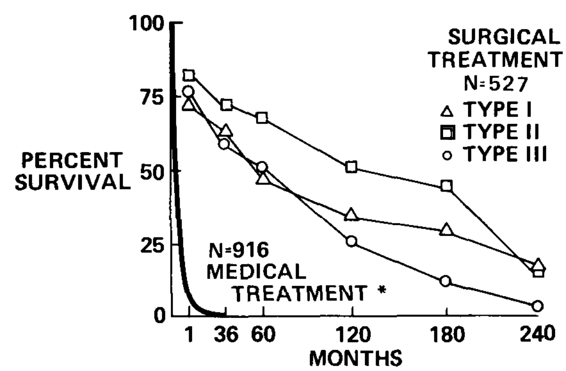

Fig. 13. Survival curves comparing medical and surgical treatment during a period of 20 years in 527 patients with dissecting aneurysms of the aorta according to type. *Data from Anagnostopoulos et al.[1]

significantly differently distributed among the types of aneurysms, with pain having the highest frequency in types I and III; congestive heart failure in types I and II; rupture in types I and III a; history of syncope/stroke in type I; and Marfan's syndrome in types I and II. Pain, syncope, peripheral ischemia, rupture, and renal failure were most significantly associated with acute stages of the disease.

Resection and Dacron graft replacement constituted the most common surgical procedure, being performed in 94% of the cases. Aortic valvular replacement was also performed in about one half of the patients with types I and II dissection.

The operative mortality rates have been progressively reduced. In the patients operated on since 1970 the figures are 20% in type I, 8% in type II, and 16% in

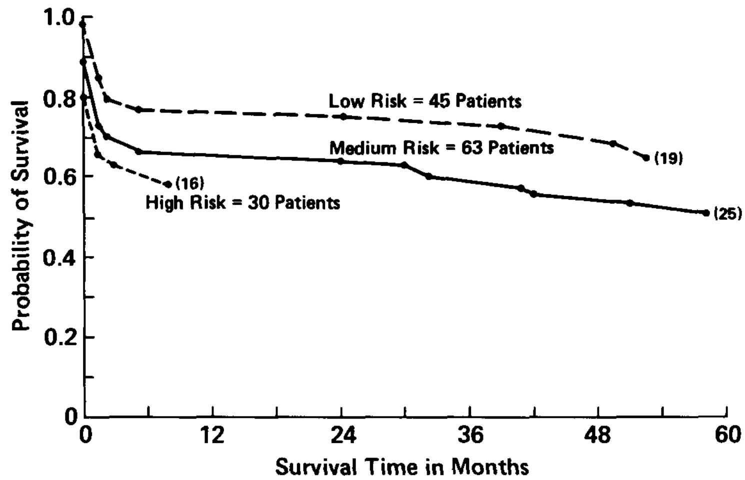

Fig. 14. Kaplan-Meier survival curves for type I dissecting aneurysms by high, medium, and low risk of overall mortality. The curves terminate at the time of last observed death. The numbers in brackets represent the number of patients remaining at risk at that time in that risk subgroup.

Table XI. Simple unadjusted χ^2 Q statistics for preoperative predictors of perioperative mortality rate (30-day)

Preoperative variable	χ^2 *Q*	*P*
Type of dissection	0.01	0.9415
Sex of patient	0.21	0.6433
Year of operation	0.02	0.8808
Age of dissection	16.75	0.0000
Diabetes	0.40	0.5270
Hypertension	2.16	0.1414
Angina	18.40	0.0000
Coronary disease (catheterization proved)	6.36	0.0117
Congestive heart failure	4.20	0.0405
Stroke	1.99	0.1582
Claudication	0.44	0.5078
Preoperative renal failure	1.22	0.2685
Marfan's syndrome	0.61	0.4347
History of trauma	0.53	0.4672
Digoxin usage	1.34	0.2465
Inderal usage	0.95	0.3297
Reserpine usage	0.11	0.7352
Diuretic usage	1.70	0.1925
Symptoms from aneurysm	7.12	0.0076
Surgical technique used	0.00	0.9815
Previous aneurysm	2.27	0.1317
Age of patient	8.82	0.0030

Table XII. Simple unadjusted χ^2 Q statistics for preoperative predictors of overall survival rate

Preoperative variable	χ^2 *Q*	*P*
Type of dissection	7.31	0.0069
Sex of patient	1.39	0.2384
Year of operation	0.05	0.8263
Age of dissection	10.38	0.0013
Diabetes	0.18	0.6739
Hypertension	6.04	0.0140
Angina	16.29	0.0001
Coronary disease (catheterization proved)	3.11	0.0778
Congestive heart failure	0.82	0.3661
Stroke	8.49	0.0036
Claudication	1.18	0.2773
Preoperative renal failure	6.50	0.0108
Marfan's syndrome	5.47	0.0193
History of trauma	0.92	0.3363
Digoxin usage	0.01	0.9107
Inderal usage	1.48	0.2235
Reserpine usage	0.01	0.9094
Diuretic usage	0.02	0.8881
Symptoms from aneurysm	4.36	0.0369
Surgical technique used	0.05	0.8280
Previous aneurysm	0.00	0.9644
Age of patient	28.77	0.0000

type III. The operative mortality rate for the acute cases was almost twice that for patients in the subacute and chronic stages in all three types. The most common causes of operative deaths were rupture, myocardial infarction, and congestive heart failure, occurring in about 25%.

Paraplegia and paraparesis were most prevalent in type III b. There has been no change in the incidence of this complication since 1970 when the various procedures previously used, such as hypothermia, shunts, left atrial femoral bypass, and femorofemoral bypass, were abandoned.

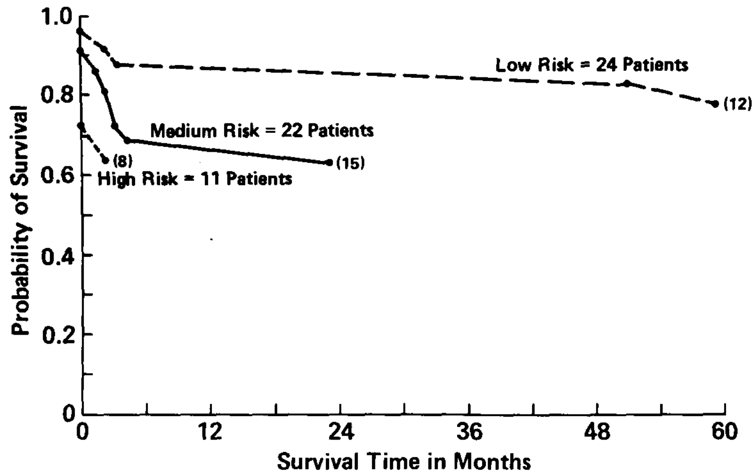

Fig. 15. Kaplan-Meier survival curves for type II dissecting aneurysms by high, medium, and low risk of overall mortality. The curves terminate at the time of last observed death. The numbers in brackets represent the number of patients remaining at risk at that time in that risk subgroup.

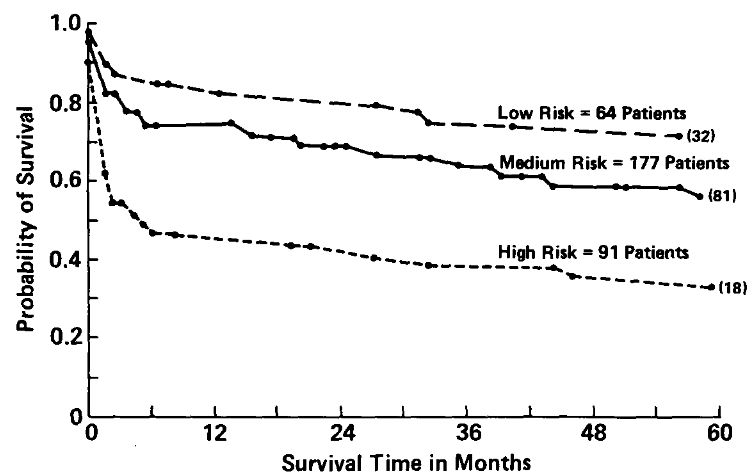

Fig. 16. Kaplan-Meier survival curves for types III a and b combined dissecting aneurysms by high, medium, and low risk of overall mortality. The curves terminate at the time of last observed death. The numbers in brackets represent the number of patients remaining at risk at that time in that risk subgroup.

Table XIII. Final Cox model estimates for preoperative predictors of perioperative survival

Variable	β	*Standard error*	χ^2	*P*
Angina	0.77035991	0.20582436	14.01	0.0002
Age of dissection	0.45818263	0.10864227	17.79	0.0000
Congestive heart failure	0.80890804	0.24453680	10.94	0.0009
Age of patient	0.01964610	0.00885908	4.92	0.0266

There is gratifying evidence from the long-term follow-up studies that surgical treatment has significantly altered the highly fatal natural course of this disease. The 5-year survival rate was 57%, the 10-year survival rate 32%, and the 20-year survival rate 5%. Types I and II had a somewhat higher rate than type III.

The most common cause of late deaths was the subsequent development and rupture of an aneurysm, accounting for 29.3% of all late deaths. Particularly

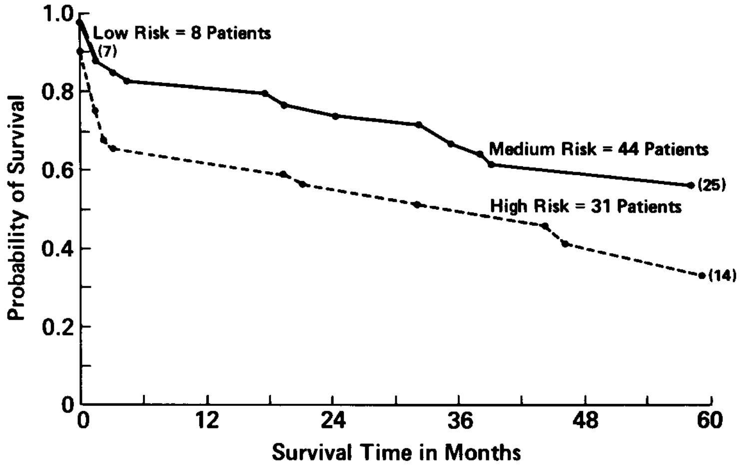

Fig. 17. Kaplan-Meier survival curves for type III a dissecting aneurysms by high, medium, and low risk of overall mortality. The curves terminate at the time of last observed death. The numbers in brackets represent the number of patients remaining at risk at that time in that risk subgroup.

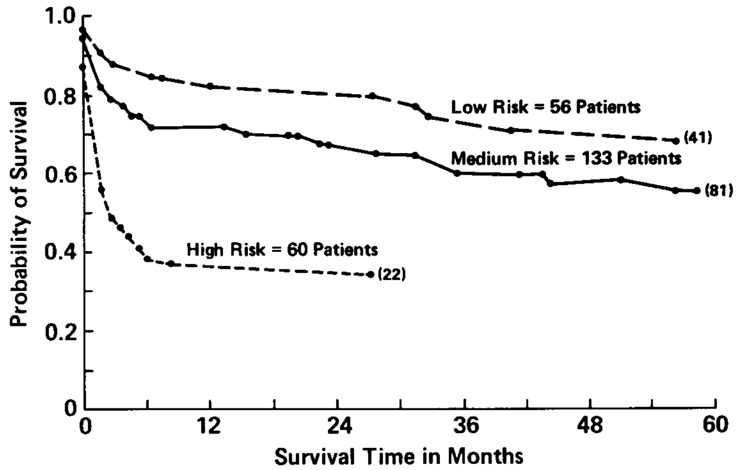

Fig. 18. Kaplan-Meier survival curves for type III b dissecting aneurysms by high, medium, and low risk of overall mortality. The curves terminate at the time of last observed death. The numbers in brackets represent the number of patients remaining at risk at that time in that risk subgroup.

noteworthy is the significant difference in the incidence of subsequent aneurysmal formation in the different types of dissection, with the highest incidences, 30% and 38%, respectively, in types I and III b in contrast with the incidences of 14% and 16%, respectively, in types II and III a. The significance of hypertension is shown by the fact that subsequent aneurysms occurred in 45.5% of patients with uncontrolled hypertension and in only 17.4% of those with controlled hypertension.

These findings in the follow-up studies on the subsequent development of aneurysmal formation emphasize the need for careful and regular periodic examinations of the patients, particularly those with types I and III b dissection, in order to detect and surgically correct this highly fatal complication. In addition, they suggest the desirability of modifying the operative procedure previously used in type III b to extend the operation into the abdomen to remove the entire dissecting process.

Another important consideration that emerged from this analysis is the identification of certain preoperative clinical factors that influence operative as well as overall survival rates. Accordingly, it was found that

Table XIV. Final Cox model estimates for preoperative predictors of overall survival

Preoperative variable	β	*Standard error*	χ^2	*P*
Age of patient	0.02520215	0.00538138	21.93	0.0000
Angina	0.45391540	0.13409555	11.46	0.0007
Age of dissection	0.20420911	0.06757246	9.13	0.0025
Stroke	0.65280781	0.27037599	5.83	0.0158
Congestive heart failure	0.32677856	0.15654318	4.36	0.0368

Table XV. Perioperative mortality rate of dissecting aortic aneurysms according to type and risk category

	Risk category				
Type	*% Low*	*% Medium*	*% High*	χ^2	*P**
I	3.2 (1/31)	26.7 (20/75)	40.6 (13/32)	12.226	<0.01
II	6.3 (1/16)	3.6 (1/28)	38.5 (5/13)	10.783	<0.01
III a	13.3 (2/15)	14.6 (6/41)	25.9 (7/27)	1.679	>0.05
III b	8.6 (6/70)	20.2 (24/119)	41.7 (25/60)	21.05	<0.01

*For significance of differences between groups derived from cross-tabulation of survival status at 1 month versus risk category.

the risk of perioperative death was higher in the elderly and in patients with preoperative angina, congestive heart failure, acute dissection, and preoperative stroke. It was also found that the preoperative factors continue to exert an unfavorable influence on late survival, an observation that emphasizes the importance of identifying and treating patients for these conditions not only during the perioperative but also in the late postoperative period.

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